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Current work and future trends for sustainable buildings in South Korea

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ABSTRACT

Korea, selected as a target nation of the second commitment period for the reduction of greenhouse gases by 2013, is making efforts to reduce the production of greenhouse gases in all industrial fields. In particular, Korea is working hard to prepare for measures on the national level to reduce energy consumption and to limit the creation of carbon dioxide in the construction industry, which is responsible for over 40% of all carbon dioxide production. In order to pursue sustainability in the construction industry, existing development-focused construction activities must be transformed via a new paradigm focusing on sustainable development through the adoption of sustainable policies by the government and the development and dissemination of sustainable construction technologies.

For such reasons, this study examined sustainable policies, research, and education recently used in Korea to identify future trends in the sustainable construction industry toward which Korea should strive in terms of governmental policy, research, education, and projects.

Contents

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1. Introduction

With recent, unprecedented climate changes from global warming becoming more adverse worldwide, discussions by the international community for establishing an appropriate response policy against climate change have become more urgent. The Fourth IPCC Assessment Report, ''Climate Change 2007,'' warns of threats to the survival of humanity from changes to the climatic environment, where global warming is no longer a far off problem, but requires our awareness as a serious threat today, such that the supreme importance of such an awareness requires handling not just at a national or regional level, but as a global response [1,2].

Korea belongs to the second group of nations requiring mandatory reduction of greenhouse gas emissions starting in 2013, for all industries, but especially for building production activities, which, due to their consumption of a great deal of energy and production of an inordinate amount of waste, have become a major focus for greenhouse gas reduction efforts. In order to maintain environmentally friendly buildings, research is necessary to develop building technologies which are ecologically sustainable, and to accurately determine the influence on the environment from building-related activities through a building's entire life cycle, including its architectural design, construction, operation, and demolition. Research is also needed to devise a suitable plan that reduces environmental demands and enhances quality of life, using the latest eco-friendly technologies, such as raw material reduction, energy saving, longer life, and recycling; shifting architectural activities from the existing focus solely on development toward a new paradigm of sustainability [3–6]. Moreover, ecologically friendly policy-making for architectural buildings, such as raw material reduction, energy saving, waste reduction, and durability improvements, must be studied for sustainable reduction of environmental demand, while improving performance as a living environment. To this end, a quantitative assessment methodology ($LCCO_2$ Assessment & Living Environment Performance Assessment) must be established for the life cycle of a building [7–11].

2. Status of adoption of policies

In Korea, a joint task team was established by the government in April 1998 following the climate change accords, with the prime minister as the chairperson. The steering function for R&D concerning the climate change accords is led by the Ministry of Education, Science and Technology, with active funding for research recently granted by the Ministry of Land, Transport and Maritime Affairs. The Korean government has been implementing various ecologically friendly, sustainable systems and policies to reduce environmental demands associated with buildings. Such policies include raw material reduction, energy saving, waste reduction, and durability improvements. These sustainable building-related systems and policies have now been in place for several years since their respective implementation, while experience gained over the time period is spurring the development of more effective systems and policies through revisions of assessment subjects and incorporation with compatible systems. Fig. 1 shows the major policies being implemented in Korea for performance assessment of sustainable buildings, as well as policies for environmental demand reduction.

Fig. 1. Sustainable building-related polices in Korea.

2.1. Building energy efficiency rating certification system

In order to achieve sound energy savings for buildings, a building energy efficiency rating certification system has been put in place for newly constructed multi-family apartment housing of more than 18 units. This provides accurate information on energy being used by each building, to help visualize economic advantages and promote investment toward energy-saving technology. This certification system assesses a building's rates of ventilation, exterior heat loss, solar heat absorption, heat loss index, interior heat absorption, heat loss index for each single unit, heating load, heating energy usage, and energy savings rate for each single unit. The total energy savings rate is divided into three classifications (Class 1: 33.5% or Better, Class 2: 23.5% ~Less Than 33.5%, Class 3: 13.5% ~ Less Than 23.5%), and long term low interest loans (Energy Usage Rationalization Fund) are provided for buildings of Energy Efficiency Rating Class 2 or better [12].

2.2. Housing Performance Rating Disclosure System

Since 9 January 2006, Korea has implemented a Housing Performance Rating Disclosure System for the purposes of ascertaining quality supply of housing as a nation, while promoting an increase in the supply of ecologically friendly housing. The system was introduced through a revision to the housing ordinance of 2005.1.8 (2006.1.9 implementation), whereby housing providers must disclose housing performance rating information regarding five areas: noise, structure, external environment, living space environment, and fire safety; under twenty odd categories, as assessed by a designated authority, when notifying invitation for tenancy on housing to become available. This system protects the rights of the consumer by allowing the potential resident to become objectively informed about the quality and performance of the housing available for selection before moving in, and it motivates the housing provider to build using reliable

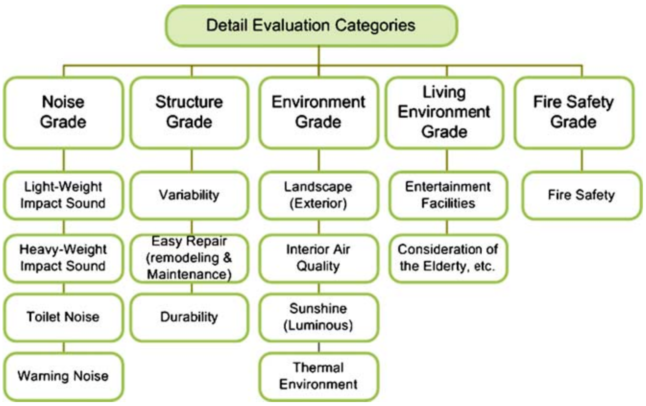

Fig. 2. Detailed evaluation categories of HPRDS.

construction, ultimately serving as a catalyst for the improvement of the national housing construction technology and industry.

The system was implemented in two phases, where the number of units required for disclosure of performance ratings was 2000 units or more for the two years 2006 and 2007, and 1000 units or more starting in 2008. Performance ratings are assessed from Level 1 through 5 based on plan documentation, with the Minister of Land, Transport and Maritime Affairs responsible for notification of regulations regarding details of performance rating assessments. The notification order delineates implementation standards for the selection, approval procedure, method, and detailed evaluation subjects by item, for the assessment organizations to conduct the housing performance rating system. Fig. 2 introduces detailed evaluation categories for each item of performance under assessment. The five performance categories are as enacted in the ordinance for noise, structure, external environment, living space environment, and fire safety, with detailed subcategories as set forth within the regulations [13].

2.3. Green Building Certification System

The original Green Building Certification System was implemented in 2002, with the Ministry of Land, Transport and Maritime Affairs taking turns every two years with the Ministry of Environment to operate a jointly adopted plan. Then with the revision to the construction ordinance in 2005.11.8, the system was overseen as certification based on law. The construction ordinance empowers the Ministers of Land, Transport and Maritime Affairs and the Ministers of Environment to jointly implement a green building certification system for the purposes of realizing sustainable development, and promoting the construction of natural resource-frugal, nature-friendly buildings. The ordinance also empowers the Ministers to enact joint regulations under the Ministries of Land, Transport and Maritime Affairs and of Environment as necessary for certification body selection standards and procedures, and to designate application procedures for approval as a certification body.

Types of facilities for approval under the green building certification system include multi-family housing units, office buildings, mixed-use residential buildings, schools, retail markets, and lodging facilities. As a norm, for already constructed buildings, the certification body issues a certificate to the approved facility under the name of the certification body itself, but a pre-certification system is in place for the building construction approval stage based on the contents of the plans only. In order to ascertain fairness of action among certification bodies, and to assure their equitable application of certification standards, the results of assessments by the certification bodies are evaluated by a certification evaluation committee comprised of experts from other certification bodies, or experts directly belonging to the certification evaluation committee. As shown in Table 1, the certification ratings are classified into two grades: First Grade and Certification Grade, and a different emblem is issued for each [14].

2.4. Evolution of the certification system

•2000. 1–12	Test Certification System Implementation (Superior Living Environment Housing Certification, Green Building Certification)
•2001. 1–12	Integration of Test Certification System (Development of Operations Plan and Multiple-Family Housing Assessment Index)
•2002. 1.1	Green Building Certification System Implementation (Multiple-Family Housing)
•2002. 1.21	Designation of Certification Body (Korea National Housing Corporation's Housing & Urban Research Institute, Korea Institute of Energy Research, Crebiz Certification Institute)
•2003. 1.1	Expansion of Certification (to Office Building, Mixed-Use Residential Building)
•2005. 3.1	Expansion of Certification (to Schools)
• 2005. 3.9	Introduction of Incentive System (3% Construction Cost Rebate for Pre-Certification)- Housing Supply Regulation, Article 13.3 (Sale Price Major Item Disclosure)
•2005.11.8	Regulatory Standard Enacted under Construction Ordinance, Article 58 (Certification of Green Building)- Ministry of Land, Transport and Maritime Affairs and Ministry of Environment currently jointly preparing enforcement order
•2006. 4.11	Multi-Family Unit Housing Certification Index Revision & Implementation
•2006. 8.24	Designation of Certification Body (Korean Institute of Educational Environment)
•2006. 9.1	Expansion of Certification (to Retail Markets, Lodging Facilities)

Table 1
Certification ratings.

Certification Grade	Score	Emblem	Note
First Grade Green Building	Above 85		100
Certification Grade Green Building	Above 65–below 85		(extra 20 points)

3. Status of education and training in sustainable building

Education and training in Korea regarding ecologically sustainable building construction can be divided into perspectives from a university or a social education. For the universities, course studies related to sustainable building construction are being expanded, with departments being realigned to graduate masters and doctorates for sustainable building technology. From a social perspective, examples are of research centers for sustainable construction and various NGO's related to the environment offering environmental awareness education for both construction-related personnel as well as the general public (Fig. 3).

3.1. Sustainable Building Research Center

On 1 June 2005, the SUSB-Research Center (Sustainable Building Research Center) was selected by the Ministry of Education, Science and Technology's Korea Science and Engineering Foundation as an Outstanding ERC (Engineering Research Center) for research related to green building construction. The SUSB-Research Center restructured Hanyang University's existing school of architecture into a course of study in sustainable construction, requiring the completion of a course in a sustainable subject as a graduation requirement for the university regardless of one's major course of study. The research center also conducts joint international video conference education with Germany's EnEd [15] for green building construction.

These sustainable construction-related courses focus on lowering a building's demand on the environment, and on improving quality of life. In addition, Hanyang University has introduced a new major course of study with a degree program in green construction, to add to the existing architecture and architectural engineering majors' programs. The new architectural environmental engineering degree includes three "Teams": "Quality of Life," "Environmental Demand," and "Productivity," to offer education and graduate thesis guidance, together with the educational steering committee [16].

Moreover, the SUSB-Research Center has been striving to expand national technological infrastructure for sustainable building, and to serve as the educational venue for joint technological innovations, by regularly sponsoring refreshers for sustainable construction, centered around construction companies and architectural professionals, to facilitate technological advancement and availability of sustainable building (Figs. 4 and 5).

3.2. Sustainable Architecture Professional Education Center

Sustainable Architecture Professional Education Center (SAPEC) is a green construction education business team selected for the

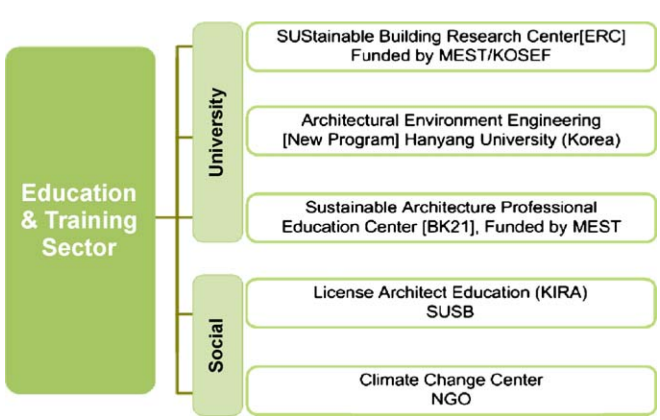

Fig. 3. Education and Training for SB in Korea.

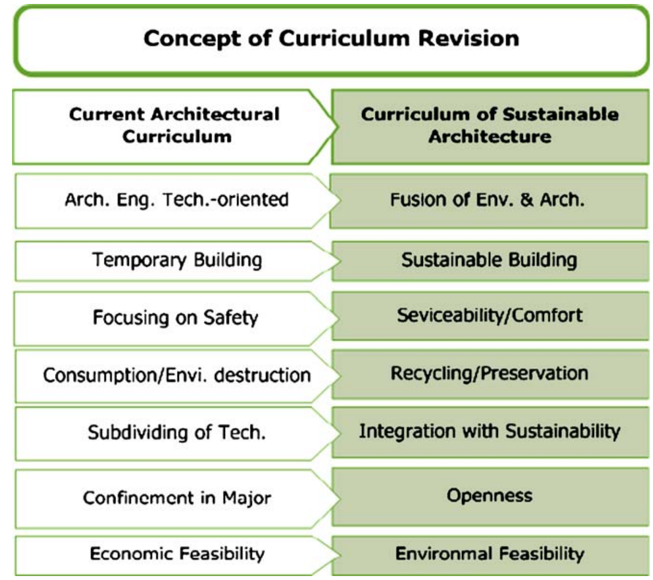

Fig. 4. Curriculum revision of SB.

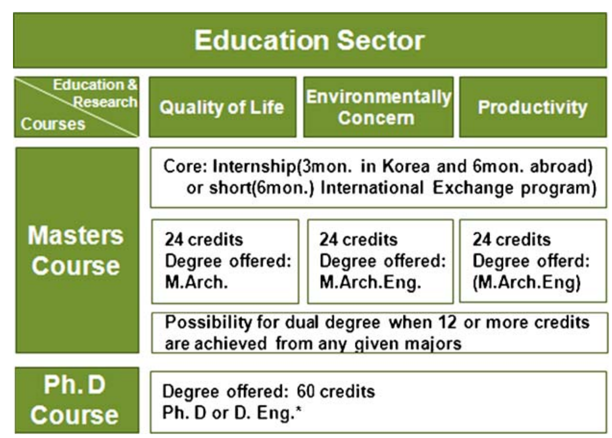

Fig. 5. Architectural environmental engineering degree.

second phase of BK21. Its goals are to preserve the Earth's environment while improving human quality of life and to fulfill the current generation's needs, without negatively impacting the future generation's ability to fulfill its own needs. Architectural development ideologies are pursued from viewpoints of quality of life, environmental impact, and construction productivity. Education of architectural technology combines sensible architectural design technology with state-of-the-art construction engineering technology, an inseparable merger of green building research and education to realize three specialized objectives: improving quality of life, reducing environmental impact, and improving productivity. In addition, to produce human resources with international competitiveness in the green, tall building market, and for technology development, SAPEC has introduced a new educational program based on the existing major study disciplines of architecture and architectural engineering, by organically combining design and engineering into an architectural environmental engineering major, as shown in Fig. 6 [17].

3.3. Climate Change Center

In Korea's Climate Change Center, the government, regional authorities, industry, and citizenry come together to raise

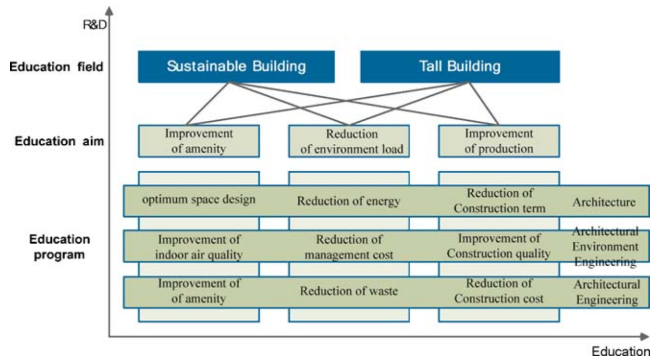

Fig. 6. Education program of SAPEC.

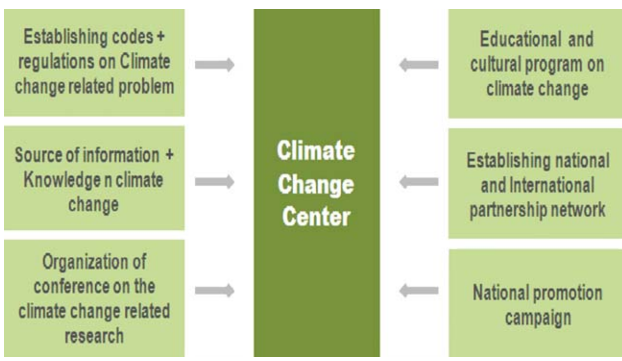

Fig. 7. Contents of the program - NGO.

awareness for global warming, and to cooperate for the purpose of seeking a response plan and solutions for the climate change problem. It also has a goal of forming a global network through international partnerships toward the preparation of a response system against the climate change problem. One of the major enterprises undertaken by this climate change center is the education of people from the government, industry, and the citizenry, through programs including the following [18] (Fig. 7).

- A climate change leadership course: providing educational opportunities for enterprise chiefs and various other industry leaders, opinion leaders to promote awareness change.
- Education for climate change response personnel professionals: A discussion type education for technical experts from the government, industry, regional authorities, and NGO's, to form a network of expertise and promote understanding among organizations.
- Citizens' Climate Change Forum: Sponsorship of public lectures by experts from various fields on an ongoing basis.
- Youth Eco Leadership Education: Raise young people's awareness about the environment through on-scene visits to climate change venues in Korea and abroad.

4. Status of adoption of new SB technologies and techniques

In order to sustain a building to be "sustainable" over duration, further research for sustainable production is necessary to accurately assess a building's effects on the Earth's environment, including those from its design, construction, and operation to its demolition, over the entire life cycle of the building. Research is also needed to come up with a response plan. As shown in Fig. 8, such a building life cycle can be designed on a Closed Loop basis, with goals to reduce environmental demands and improve livability, using state-of-the-art green techniques for raw material reduction, energy savings, longer life cycle, and recycling. There is a need to steer building construction activities from the existing mindset of ever-increasing growth to a new paradigm of sustainable growth [19,20]. For the purpose of preserving the Earth's environment, research is needed to improve the quality of living environments while reducing demands on the environment, as well as to use green technology policies for raw material reduction, energy savings, waste material reduction, and increased durability. What is needed is a quantitative assessment metric for the life cycle of a building (LCCO_2 & living environment performance assessments) [21]. For these purposes, a number of research projects are underway in Korea under government sponsorship for ecologically sound building construction. Fig. 9 shows areas of research for sustainable growth building led by the Korean government.

4.1. Sustainable Building Research Center

The SUSB-Research Center (Sustainable Building Research Center) is the sole Outstanding Engineering Research Center (ERC) in the field of architecture in Korea, designated on 1 June 2005 by the Ministry of Education, Science and Technology's Korea

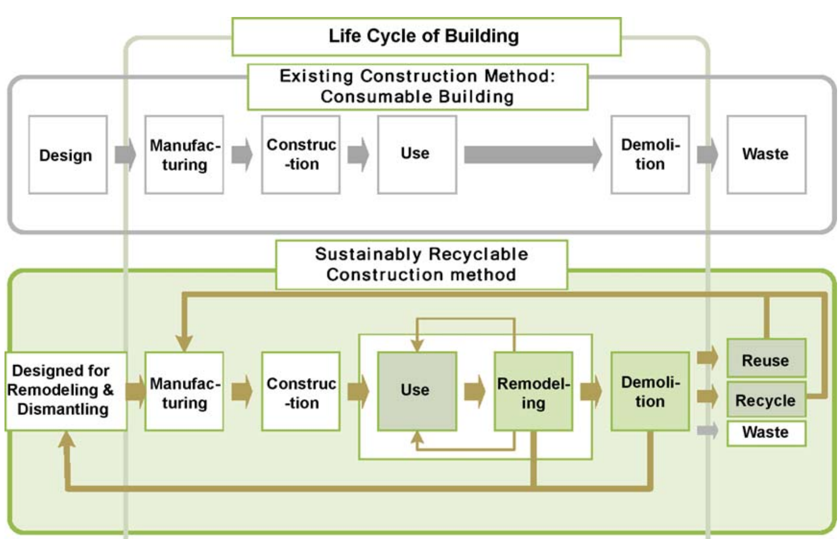

Fig. 8. Sustainable, recyclable construction method.

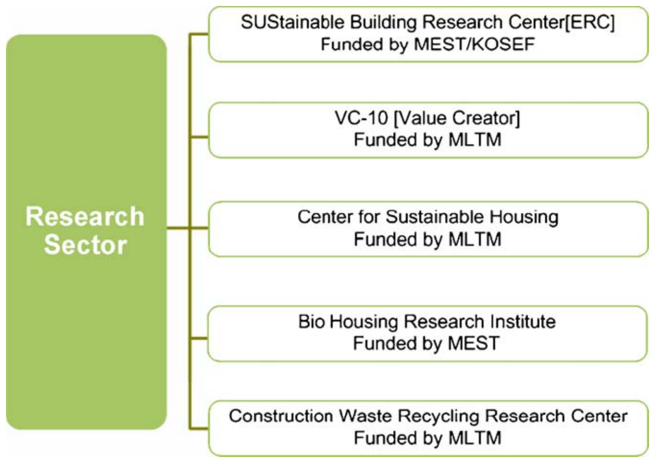

Fig. 9. Education and training for new SB technologies and techniques in Korea.

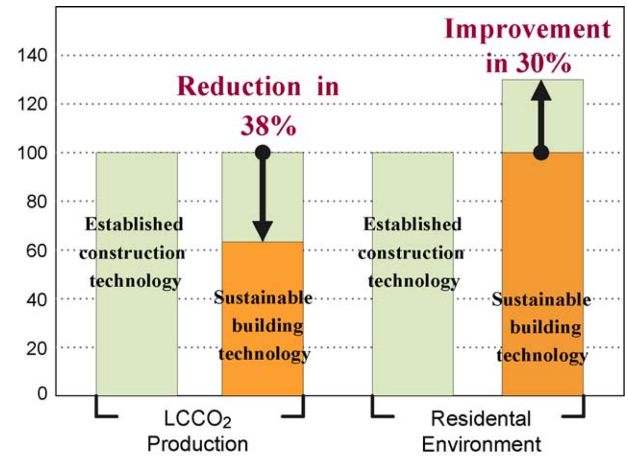

Fig. 10. Technical goals of SUSB.

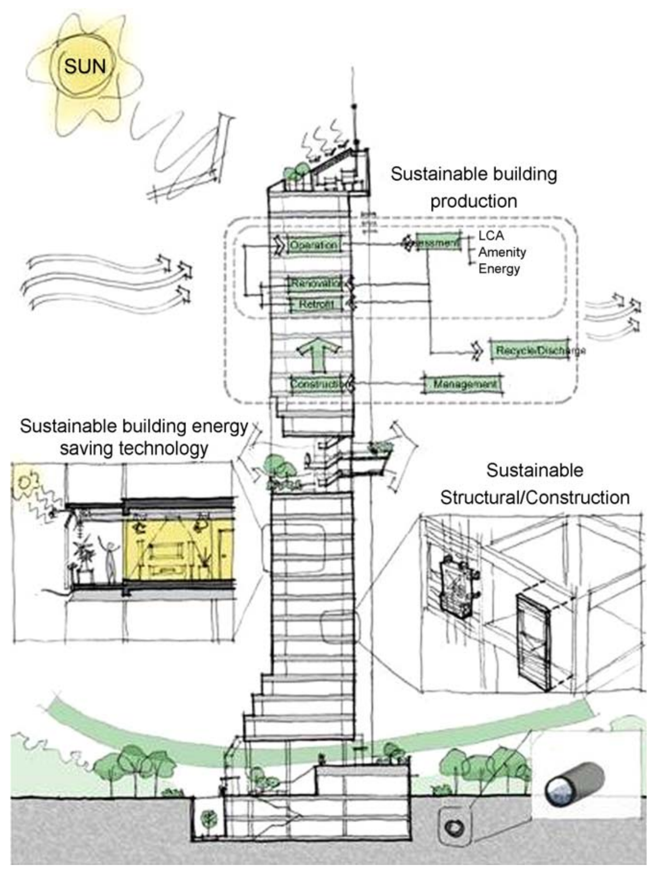

Fig. 11. Prototype research method.

Science and Engineering Foundation. SUSB-Research Center's chartered mission is to develop architectural engineering technology to protect the Earth's environment and improve quality of life, by establishing a sustainable building construction technology system of world renown.

To such an end, research and development efforts are underway with key technologies for optimal planning and resource reduction, demand reduction and energy savings, modularisation—automation and waste material reduction, and durability improvements and maintenance LCC reduction. Sustainable technologies thus developed are incorporated into a university curriculum through the Technology Academy and the Environment Academy, to raise environment technicians of high caliber. These technologies are transferred to the industry for application, under a regulatory framework, and are expanded to a social movement for the environment.

The ultimate research objective for the SUSB-Research Center, in preserving the Earth's environment and improving the quality of human life, is to integrate various key construction technologies to build a sustainable high-rise building (30-story residential building) of world renown. In terms of numbers, the stated research goals are first, to reduce environmental demand by capping CO_2 production for a 38% reduction for the life cycle of the building ($LCCO_2$), and second, to improve living environment performance by 30% for the life cycle of the building (quality of life improvement). For this purpose, SUSB-Research Center has established deliverable goals for the entire life cycle of a building, from design, construction, operation and maintenance to demolition, for each area of activity for building production, such as resource-saving manufacturing technology, energy-saving environmental technology, waste-reducing construction technology, and improved durability operation and maintenance technology, with research integrated across disciplines. The 38% reduction in $LCCO_2$ and the 30% improvement in living environment performance as the stated objectives of this research shall be achieved through the development of technologies for the life cycle of the building, for each area of CO_2 reduction and living environment performance improvement, simultaneously with the development of assessment indices and programs for the quantitative analyses of the developed technologies, and through validation processes involving feedback for each phase of the research [22] (Figs. 10 and 11).

- *Final Research Goals*: Realization of sustainable high-rise building by combining various technologies for the purpose of environmental conservation with improved quality of life.
- *Quantitative Final Research*: Reduction of total CO_2 by 38% through the life cycle of the building. Improvement of amenity by 30% through the life cycle of the building.

4.1.1. Assessment programs development for building environmental demand and quality of life

For the purpose of meeting objectives for quantitative assessment, SUSB-Research Center developed a building life cycle environmental demand assessment program (SUSB-LCA ver. 1.0) and a building resident human quality of life assessment program (SUSB-SAM ver. 1.0). For the SUSB-LCA ver. 1.0, input conditions of the building's resource usage by type of material, energy usage for the operational duration, and waste material produced for the

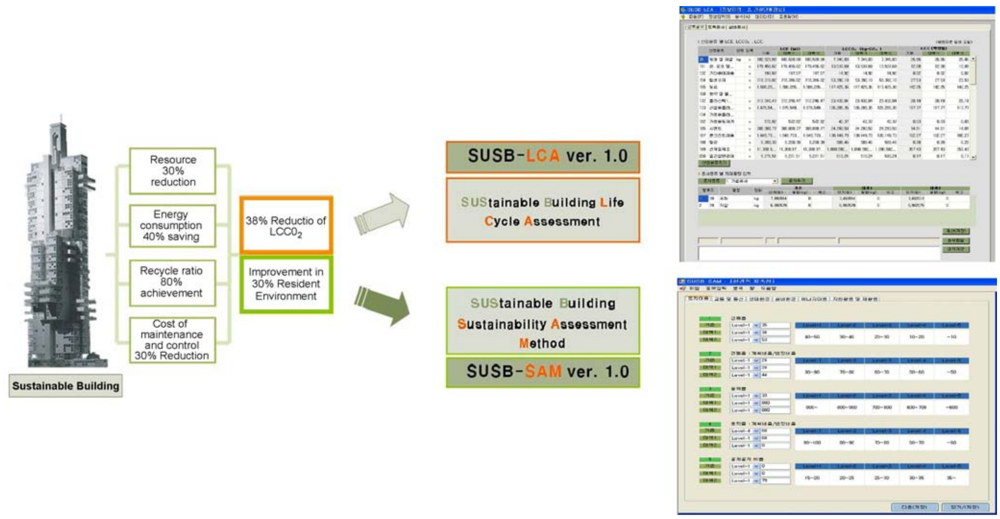

Fig. 12. SUSB-LCA ver.1.0 & SUSB-SAM ver.1.0.

demolition phase allow the calculation for the life cycle of the building for LCE (Life Cycle Energy), $LCCO_2$ (Life Cycle CO_2) and LCC (Life Cycle Cost). The assessment program makes possible a comparison against existing buildings in reductions of LCE (Life Cycle Energy), $LCCO_2$ (Life Cycle CO_2) and LCC (Life Cycle Cost) for buildings constructed with sustainable engineering technologies [23] (Fig. 12).

4.1.2. Test bed for performance assessment of sustainable building

SUSB-Research Center has built a Wind Environmental Laboratory as a Test Bed for various sustainable technologies developed at the center, including its dual external surfacing technology. This test bed measures in real time air movement and temperature change within the wall gap. Data collected are analyzed and used in designing an optimal dual surfacing system to minimize energy usage. The wind test equipment at the facility can also be used to assess a city's heat island effect and wind current movements, as well as to test a high-rise building's wind pressure and vibration effects (Fig. 13).

4.2. Center for Sustainable Housing

The Center for Sustainable Housing (CSH) was founded for the purpose of developing model apartment housing of low energy construction and sound environmental technology. This housing is to be built in New Town developments under policies for balanced national growth, promoting sustained growth for the new town communities, and establishing a system for the government to provide policy incentives for a low-energy eco-friendly public apartment market, while encouraging continual research, development, and market application. Therefore, the purposes of its research and development were the design of model sustainable apartments for the construction market, the creation of a low energy sustainable apartment infrastructural program (SH-2011 Program), and the establishment of the CSH in support thereof. The SH-2011 is a national program under a new concept to promote the establishment of a low-energy/sustainable market, and it includes the supply of related products and housing real estate. With a technological goal of a 'Low-Energy Sustainable Apartment,' the program provides policy support to meet stated objectives, with new goals asserted from time to time, in order to accelerate technical advancement, and to lead the low-energy sustainable construction industry for the nation [24].

4.3. Bio Housing Research Institute

The Bio Housing Research Group, appointed by the Korean Ministry of Education in August 2005, is a part of bio housing development research that combines environment-friendly material and cutting-edge construction technology. The group is carrying out vigorous activities to develop industrial brands that can maximize the value of regional characteristics of natural resources of Kwangju, Jeonnam [25].

(a) Wind environment laboratory (b) Air current & temperature measurement (c) Wind testing

Fig. 13. Wind environmental laboratory.

4.4. Construction Waste Recycling Research Center

The Long Life Housing Research Group was appointed by the Korean Ministry of Construction and Transportation as part of construction core technology research and development in 2005. The group is carrying out research on foundation technology and will be working on the development of a Korean long life standard model with durability and alterability, until 2010.

"Construction waste recycling real rate is 80%" is the ultimate object of this research. To meet it, the procedure is divided into 3 steps: production of construction waste, processing, and recycling. To realize this objective, we set three research and development goals [26].

5. Status of adoption of SB Whole-Building Performance Rating Systems

5.1. The Environment-Friendly Housing Certification

The Korea National Housing Corporation's Housing & Urban Research Institute conducted a three-year national research project starting in 1996 for the Ministry of Land, Transport and Maritime Affairs, to develop an assessment model for performance ratings of housing projects based on their standards of synergy with the environment, together with a plan to utilize the model as a certification system. The MLTM had also seen the need for development of housing which is in harmony with the environment, and assigned the project for a systematic plan to the Urban Research Institute, aiming toward a seminal examination of assessment methodology and procedures necessary for a housing certification system. The Urban Research Institute conducted a pilot assessment of eco-friendly housing in February of 2000 with twelve domestic construction companies for new housing projects, striving to validate in actual application the eco-friendly housing assessment model developed through the national research project. The results of these pilot assessments were applied in updating the evaluation metrics and standards for the housing assessment model, to ultimately complete the "Superior Living Environment Housing Pilot Certification Assessment Model" with input by experts from the government and outside. In September 2000, the "Superior Living Environment Housing Pilot Certification" system was implemented to grant certification for eight of the projects.

5.2. Green Building Pilot Certification System

In order to prepare an operational structure and operating regulations for the certification system, the Korea Management Association Registrations and Assessments, Inc. (KMAR) conducted a green building pilot certification program in 2000, based on results from a study by the 'Environmental Policy Research Committee', developing operational procedures with related regulations for the green building certification system, and using the pilot certification program's actual assessment applications to tweak problems associated with its operations and technology. To this end, KMAR was contracted for consignment service by the Ministry of Environment for the performance of a green building pilot certification program [27].

5.3. Green building certification criteria

Since the Green Building Certification Standard bill was announced in 1997 by the Green Building Technology Research Committee, eco-friendly building certification systems have been studied by the Korea National Housing Corporation's Housing & Urban Research Institute, Crebiz Certification Institute, the Korea Institute of Energy Research and the Korea Institute of Construction Technology. Then, following a process of integration for the green building certification system by the Ministry of Land, Transport and Maritime Affairs and the Ministry of Environment, the certification standard for apartments was implemented on 1 January 2002 (Revised 2006.4.11). At present, certification standards are in effect for mixed-use residential and office buildings (2003.1.1), schools (2005.3.1), and retail markets and lodging facilities (2006.9.1). Regardless of the type of usage for the building, the assessment criteria for the GBCC are divided into 4 areas (① Land Usage & Transportation ② Energy Resource & Environmental Demand ③ Ecological Environment ④ Interior Environment), and 9 subcategories (① Land Usage ② Transportation ③ Energy ④ Materials & Resources ⑤ Water Supply ⑥ Air Pollution ⑦ Maintenance ⑧ Ecological Environment ⑨ Interior Environment), with each item graded independently. Again, without regard for the type of usage for the building, if the rated score (normalized to a scale of 100) falls between 65 and 84 inclusive, a rating of "Excellent" is granted, while a score of 85 or better receives a "Superior" rating. As for its proliferation, the GBCC as of 2006.3.31 had certified 85 cases, but by 2006.12 had significantly increased to 204 cases. Perhaps such was the reason behind the enactment of Article 58 in 2005.11.8 to the Construction Act (Certification of Green Buildings), and the revision, made on 2006.2.24 to Article 13 of the Regulation Related to Housing Supply (Introduction of an Incentive System for the Green Building Certification of Apartments). Other proposals are on the table to further strengthen green building certification systems in Korea, with systematic plans for facilitation of eco-friendly buildings as public facilities through incentives, along with the development of programs dedicated to the green building certification system. Table 2 shows areas and subcategories for GBCC of apartment buildings as revised on 2006.3.12 [28–30] (Tables 3 and 4).

5.3.1. Case study: Green Building Certification

The first case among apartments to receive a "SUPERIOR" rating through the Green Building Certification System (Both Pre-Certification & Main) (Figs. 14 and 15).

(1) Building General Information

•Building Name	I'PARK Samsung-dong		
•Location	87 Samsung-dong Gangnam-gu, Seoul		
•Constructor	Hyundai Development Company		
•Surface Area	32,259 m^2	•Bulk	296.32%
•Building Area	2,960.50 m^2	•Landscape 50.63%	50.63%
•Total Floor Area	146,482.92 m^2	•Number of Households	449
•Building to Land Ratio	9.18%		

(2) Notes on Assessment for Green Certification

Assessment areas	Notes
Land Usage & Transportation	•Easy access to city center (approx 800m distance to the COEX) •Bicycle route & parking available •Exclusive pedestrian walkway (length 350 m) •Easy access to mass transportation—subway & bus •Integral community center
Energy Resource &	•Flexible floor plan for the duration of life cycle
Environmental Demand	•Food waste drain & other scrap waste storage facility installed •Ultra high speed (Class 1) data communication with apartment contents accessible through the internet •Water usage reduction (ultra water saving toilet) & drainage •Use of eco-friendly material (Eco Mark, GR Mark Products) •Application of new construction technology & industrialized construction techniques •Water reclamation installation (used to feed a stream)
Ecological Environment	•Aquatic biotope (brooks, ponds) and terrarium biotope built in •High green herbage ratio of 50% •Continuous green tract of land along the length of complex •Ecologically sensitive artificial green landscaping: green biological revetments, retaining walls
Interior Environment	•Use of materials with low volatile organs ic compound fumes •Individual room temperature control units on all apartments •Good sound insulation of walls between units •Good sunlight illumination of each unit interior

Table 2
Assessment items for GBCC-Multiple-family housing.

Assessment areas	Subcategories	Assessment items
Land Usage & Transportation	Land Usage	1. Ecological Value 2. Land Usage 3. Effect on Nearby Land
	Transportation	1. Reduction in Transportation
Energy Resource & Environmental Demand	Energy	1. Energy Usage 2. Energy Savings
	Materials & Resources	1. Resource Savings 2. Resource Recycling
	Water Resource	1. Water Recycling 2. Water Resource Savings
	Air Pollution	1. Global Warming Prevention
	Maintenance	1. Systematic Management 2. Effective Management 3. System Adaptability to Change
Ecological Environment	Ecological Environment	1. Green Area within Site 2. Nature Area within Site
Interior Environment	Interior Environment	1. Air Environment 2. Heating Environment 3. Noise Environment 4. Livability 5. Considerations for Elderly

6. The future trends for sustainability in South Korea

Future trends for sustainable buildings in Korea are discussed. First, as shown under Fig. 16, future trends for sustainable building-related joint activities by industry, academia, and R&D will be discussed by categorizing them under the titles of Government (Policy & Regulation), Research, Education, & Project. Data indicate trends for a sustainable building to change from the current concept of Green Building to a notion of Sustainable Building, with elements of social, economic and city planning mixed in, thereby requiring research in this direction.

For the Government Sector, in keeping up with these trends of the time, transition is required from the current green building certification system to an assessment system for sustainable buildings, with consideration of buildings' eco-friendly performance at the level of an entire region, introducing sustainable performance assessment and development, and considering the city along with building construction. Indeed these efforts surpass regional or even

Table 3
Certification results by years.

	Year					Total
	2002	2003	2004	2005	2006	
Certification results	3	4	14	33	163	217

Table 4
Certification results by type of building usage.

	Building type				Total
	Multiple-Family Housing	Office building	Mixed-use Residential building	School	
Certification results	171	32	7	7	217

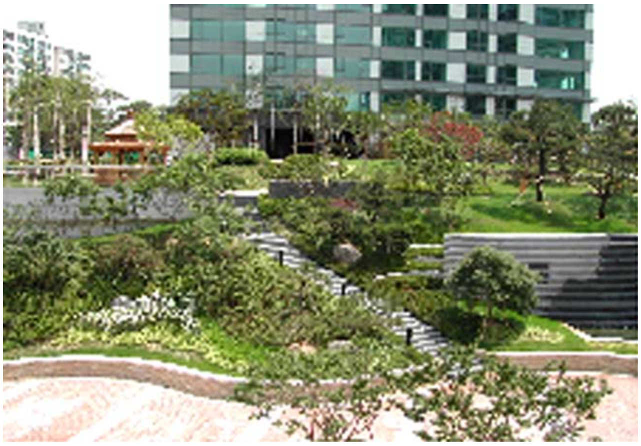

Fig. 14. Biotope terrarium.

Fig. 15. Automatic room temperature control unit.

national undertaking, requiring an international alliance of sustainable networking systems to become effective. Currently in many countries of the world, CO_2-Neutral cities have been promulgated, with myriad efforts underway to rein in further CO_2 increase. CO_2 reduction technology development and related assessment for building constructions will no doubt play an important role for the realization of carbon neutral cities. Recently, MACCA, the Korean Multifunctional Administrative City Construction Agency for the new administration capital to be built in South Chungcheong Province's YeonGi-Gun declared that MAC will be built as a CO_2 neutral city [31], and active research has been underway in concert with SUSB-Research Center [16]. The details of these R&D efforts are introduced below under the heading 6.1 Sustainable Multifunctional Administrative City—CO_2-Neutral City.

Sector	Current Work	Future Trend
Government	▶ GB Rating/certification ▶ Domestic Building Level	▶ SB Rating / Building-Urban ▶ International Alliance
Research	▶ Separated works ▶ Qualitative assessment ▶ Green Building Level	▶ Convergence works / ▶ Quantitative LCA ▶ Sustainable Building / City / Country Level
Education	▶ University Education ▶ Architectural Education ▶ Domestic Level	▶ Social/International Education ▶ Fusion Education (SOS) ▶ International Level (ISOS)
Project	▶ Building Level Project ▶ Government Project	▶ Nation Wide Project ▶ Civilian Project

Fig. 16. Future trend for sustainability in South Korea.

For the Research Sector, then, transition is required from the current qualitative type of assessment technology development at the level of green buildings, to quantitative types of assessment technology development for metropolitan and national scale sustainable building levels. For the Education Sector as well, education confined to a region or a university, and architectural venues, must be opened up to form international networks for sustainable education, tapping into various learning systems to transition into to a global educational era focusing on the environment. Finally, for the Project Sector, it is also deemed timely for transition from building level projects to nation-wide projects, illuminating tall buildings, seen with keen interest the world over, and dissociating them from the excessive energy demand of past constructions, to hasten research for environmentally sustainable tall building technology, through the development of sustainable building engineering technologies and assessment methodologies.

6.1. Sustainable multifunctional administrative city—CO_2-Neutral City

The Multifunctional Administrative City for Korea is a national project to alleviate concentration around the capital city of Seoul, toward the furtherance of equitable growth as a nation. As an administrative capital, the government of Korea has planned a new city of population 500,000 to be located in YeonGi-Gun of South Chungcheong Province (150 km from Seoul). For completion by 2030, the MAC is to be built as an environmentally friendly city tailored to the characteristics of Korea from the planning stage on, for transportation, energy, and other areas of reductional applications, with thorough management systems to save approximately 32% on energy expenditures, and to reduce CO_2 output by 25%. MACCA, the Multifunctional Administrative City Construction Agency in charge of the undertaking, has declared MAC to be a CO_2-Neutral City, and has been striving to develop technology and international networking necessary to attain this objective. Currently, environmentally friendly building research institutes in Korea are engaged in research projects to define tangible applications for the realization of MAC as a CO_2-Neutral city (Fig. 17).

Fig. 17. Map of Multifunctional Administrative City.

▪Construction Period	2005–2030
▪Area	73.14 km^2
▪Population	500,000

Vision	Realization of CO_2 neutral city, Sustainable city, international engineering science, government city: world's leader in sustainable-related industry	
Aim	▪32.8% reduction in energy consumption ▪25% reduction in CO_2 emission ▪Establishing the HUB, an international Sustainability center	
	Stage 1	Building level construction of sustainable building
	Stage 2	Urban level construction of sustainable building
	Stage 3	Global level common network and establishing a HUB

6.2. $LCCO_2$ quantitative assessment—building, urban, national, and global levels

Throughout the world today, efforts are being made for environmental demand reductions such as in the development of CO_2-Neutral Cities at metropolitan and national levels. To achieve this goal, new developments are necessary to expand upon technologies for assessment of environmental loads at a building construction level, to enable quantitative assessment of total environmental demand at the level of an entire city or even a country. Accordingly, transition is inevitable from the current development for qualitative assessment technology at a green building level, to that of quantitative assessment technology levels on par with city-wide and national scale sustainable buildings. Aware of this paradigm change, as just introduced in 6.1 above, Korea has been conducting research for technology development to enable the measurement not only at the building level for the construction of a CO_2-Neutral City, but at a metropolitan level for quantitatively assessing environmental demand toward load reduction (Fig. 18).

Fig. 19. International sustainability education network.

6.3. International sustainability educational network—ISOS (International School of Sustainability)

It is necessary to raise specialized human resources with competitiveness for the international arena, through the establishment of an international sustainability friendly educational network centered around architecture. At present, in Korean educational institutions (Hanyang University, Seoul National University, KAIST, etc.), through interdisciplinary studies across fields, internationally capable, specialized personnel are being trained, and are also striving to raise their universities' standings in the world (Fig. 19).

6.4. Sustainable tall building

Recently, international demand for tall buildings has been rising exponentially. Korea is one of the countries where tall building construction is progressing actively, and ranks fourth in the world for buildings rising over 100 stories high. Demand for such schemes of vertical urban development using very tall buildings is expected to increase for some time. However, such large buildings have become known as being antagonistic to the ecologically friendly trend for buildings, due to their excessive energy usage during the construction phase and thereafter through their operation. However, recent applications of sustainable

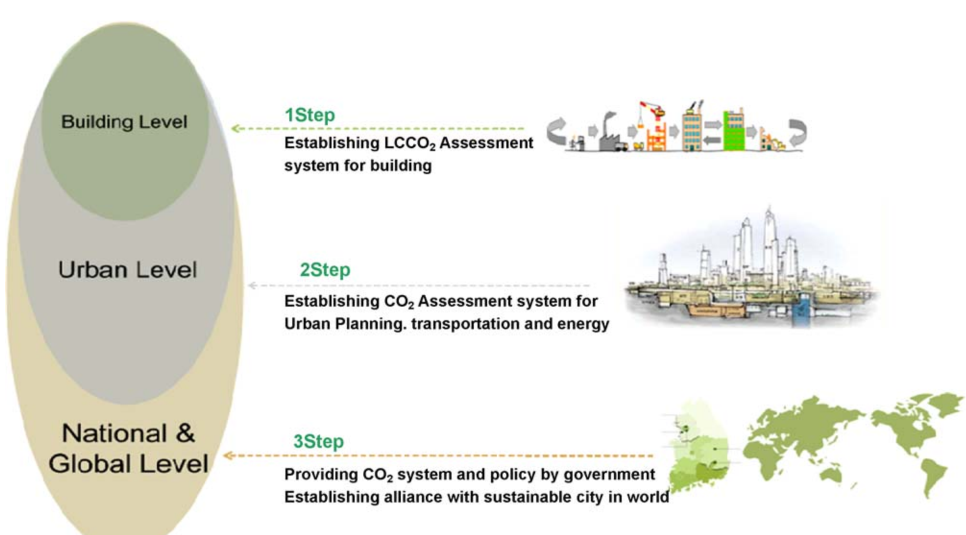

Fig. 18. Levels of assessment and networking: building, urban and national/global.

Fig. 20. Sustainability and tall building.

technology to these tall buildings are attempting an image makeover as part of the sustainable family of buildings with reduced environmental demands. Some of the sustainable application technologies are double-skin, and the use of wind and solar types of renewable energy. Further development is necessary for sustainable building technology of various means for application to tall buildings, along with a method of assessment [32] (Fig. 20).

7. Conclusion

This paper has discussed the current situation for environmentally friendly building construction in Korea from the standpoints of public policy, education, and research, with examples of cases for application. It has also touched the future trend for sustainability friendly building construction in Korea, from governmental policy, education, research, and project perspectives. Sustained environmental viability is the subject of discussion for our global community today, and transition of architectural building constructions toward a sustainability industry for the sake of preserving our Earth's environment is now a critical necessity.

To this end, a pro-environmental international network should be formed with sustainable building at its core, with information exchange for each country's policies and eco-friendly technologies, in order for the building sector to rise to the challenge of protecting our Earth together.

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References

[1] Urushizaki N, Mizuno M, Shimoda Y. The study on life-cycle waste and CO_2 emission from countermeasure of long-life building. J Archit Plan Environ Eng AIJ 2003;563:93–100.
[2] Forsberg A, von Malmborg Fredrik. Tools for environmental assessment of the built environment. Build Environ 2004;39:223–8.
[3] Li Z. A new life cycle impact assessment approach for building. Build Environ 2006;41:1414–22.
[4] Zhang Z, Shu X, Yang X, Zhu Y. BEPAS—a life cycle building environmental performance assessment model. Build Environ 1990;41:669–75.
[5] Sjostrom C. Approaches to sustainability in building construction. Struct Concrete 2001;3:111–9.
[6] Excerpts edited from KIM DG. Basic Environmental & Economical Comparison Analyses of Reinforced vs. Concrete Bridges Using Life Cycle Assessment Methodology. Korea Advanced Institute of Science and Technology. Master thesis 1995; 23–25.
[7] Urie A, Dagg S. Development of a life cycle assessment (LCA) based decision-making tool for the assessment of building products. J Environ Assess Policy Manage 2004;6:153–76.
[8] Ardente F, Beccali M, Cellura M, Mistretta M. A LCA case study of kenaf-fibres insulation board. Build Energy Perform 2008;40:1–10.
[9] Jonsson A, Bjoerklund T Tillmann. LCA of concrete and steel building frames. Int J Life Cycle Assess 1998;3:216–24.
[10] Japan Resource Institute. LCA Methodology, energy. Resource 1996; 6: 26–35.
[11] Vorsatz DU, Danny Harvey LD, Mirasgedis S, Levine MD. Mitigating CO_2 emission from energy use in the world's buildings. Build Res Inform 2007;35:379–98.
[12] Korea Energy Management Corporation. http://kempia.kemco.or.kr/efficiency_system/home/index.asp.
[13] Suh MK. Housing Environment Policy Environ-friendly Housing Assessment System of Korea. In: International Seminar for "The Performance Evaluation of Sustainable Building and the Regulatory System of each Nation", 1. 2006. p. 13–22.
[14] Oh SH. Green Building Certification System and Certificated Cases in Korea. In: Sustainable building efficiency. Seoul: Kimoondang Publishing Co.; 2007 p. 54–90.
[15] International Education Center for Energy System. http://www.ened.com.
[16] Susbtainable Building Research Center. http://www.susb.hanyang.ac.kr.
[17] Sustainable Architecture Professional Education Center. http://sapec-hyu.org.
[18] Climate Change Center. http://www.climatechangecenter.kr.
[19] Malhotra V Mohan. Reducing CO_2 emissions. Concrete International; 2006 September. p. 42–57.
[20] Jönsson Åsa. Tool and methods for environmental assessment of building products-methodological analysis of six selected approach. Build Environ 2000;35:223–38.
[21] Soebarto VI, Williamson TJ. Multi-criteria assessment of building performance: theory and implementation. Build Environ 2001;39:681–90.
[22] Shin SW. Sustainable building technology. Seoul: Kimoondang Publishing Co.; 2007. p. 11–29.
[23] Shin SW, Tae SH, Lee KH. The $LCCO_2$ reduction effect and economical evaluation of the reinforced concrete structure using high strength concrete. In: SB08 Melbourne World Sustainable Building Conference. 2008. p. 88.
[24] Center for Sustainable Housing. http://www.bet.yonsei.ac.kr.
[25] Bio Housing Research Institute. http://www.biohousing.re.kr.
[26] Construction Waste Recycling Research Center. http://www.cwrcenteer.re.kr.
[27] Green Building Pilot Certification System. http://www.kmar.or.kr.
[28] Korea Green Building Council. http://www.greenbuilding.or.kr.
[29] Kim YR, Tae SH, Shin SW, Lim SC, Leigh SB. A study on Indoor Environmental Ratings by Comparing Green Building Certification Systems through case studies. In: SB07 Seoul International Conference on Sustainable Building Asia. 2007. p. 107–12.
[30] Lee JS, Maeng JC, Lee SH, Lee YS. A study on method of application and activation of the Green Building Rating Systems in the Subject of Apartment Housing. In: SB07 Seoul International Conference on Sustainable Building Asia. 2007. p. 95–100.
[31] Multifunctional Administrative City Construction Agency. http://www.macc.go.kr.
[32] Korea Super Tall Building Forum. http://www.supertall.or.kr.